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RIM DEFORMATIONS OF THIN-RIMMED GEAR WITH MIDDLE WEB STRUCTURE

DEFORMACE TENCE LEMOVANÉHO OKRAJE SOUKOLÍ SE STŘEDNÍ LAMELOVOU STRUKTUROU

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Abstract

The paper deals with the 3D FEM calculations to evaluate the deformations that occur at the rim of thin-rimmed gear with middle web structure. The developed model of a pinion-wheel system enables the torque transmission and the tooth load distribution resulting from actual wheel structure. The analysis of maximum rim deformations expressed in dimensionless form, is performed for several combinations of thin rim and web thicknesses. The effects of thin-rimmed spur gear three-dimensionality on the rim deformation are investigated too, considering the gears with narrow and much wider faces.

Key words: spur thin-rimmed gear, displacement, web

1. Introduction

The elasticity of gear body influences the magnitude of tooth deformation and its effect upon gear performance. When gear teeth have complex support comprised of thin rim connected by web to a hub, it becomes necessary to clarify in detail the modus of these elements deformation.

Through numerous early works was confirmed that the deformations of gear teeth base are engaged significantly in total tooth deflection. The composition of tooth deflection has been analysed in detail and the tooth compliance equations were developed [1]. Analytical expressions cover three main components that effect the resulting tooth deflection i.e. the basic deflection of the tooth treated as a nonuniform cantilever beam, the tooth deflection caused by fillet and foundation flexibility and local deformation caused by the contact between the two mating teeth.

The use of numerical methods, being the FEM predominant one, has intensified the investigation of tooth deflection as actual gear structure and its contribution, can be embraced. This has been welcome answer to meet the requirements for a gear weight reduction by finding the possible design recommendations. The 2D FEM investigation along with experiment was performed for thin-rimmed gears with spokes [2]. It was found that the deforming condition of a spur gear varies with the meshing teeth.

The 3D FEM calculations of stresses and deformations of thin-rimmed gear with offset web structure were presented in [3]. Valuable results are based upon careful analysis of the adopted model related to satisfactorily simulation of pinion-wheel deformations.

The accepted conventional approach neglects spur gear three-dimensionality and many researches at first relied on this simplification. On the contrary, the results of investigations that took into account actual spur gear, have confirmed considerable differences in the gear state of stress and strain, related to 2D approach. Three-dimensional aspects of gear tooth base deflections were investigated and the results were utilized for the development of a simplified model to predict the base rotation effects of gear tooth deflection [4].

The aim of this work has been to put together the influences of geometrical parameters of thin-rimmed gear with middle web structure, the rim and web thicknesses, along with the gear face width i.e. the influence of gear three-dimensionality, upon the rim deformations.

2. Considerations of three-dimensional FEM analysis

The 3D FEM model is assumed of thin-rimmed wheel structure with middle web, mating with a solid pinion. The thin-rimmed wheel is modelled with three teeth above entire ring that has enlarged rim thickness corresponding to the rigidity of the omitted teeth. The pinion model has angular extension that corresponds to four teeth, but three teeth are modelled above ring.

The aspects of gear three-dimensionality are taken into account by the gear face width corresponding to narrow and wide faced gear (Fig. 1). For wide faced gear, the face width b is greater than four times the tooth height h_t (b/m =10, m – module, mm), and for narrow faced one the face width is less than it (b/m =4) [4].

The range of thin rim thickness s_R covers the backup ratio s_R/h_t from 0,44; 0,64; 0,92 to 1,33, which slightly overcomes upper and lower limit proposed by the standard ISO [5]. The web thickness b_s/b is adopted: b_s/b=0,1; 0,2; 0,3 and 0,4.

The pinion and wheel differ only through the structure of their bodies, having equal other geometrical parameters. The pinion and wheel teeth parameters are number of teeth z_1=z_2=20, module m=10 mm, pressure angle α_n=20°, profile shift coefficient x_1=x_2=0, and contact ratio ε_α=1,56.

As regards different face widths of the wheel, the relations of rim thickness s_R/h_t and web thickness b_s/b, are kept constant for certain actual face width value. The engagement is established at the outer point of single pair tooth contact. Due to the symmetry of geometry and load, the model with one half of actual face width is utilized, as shown in Fig. 1.

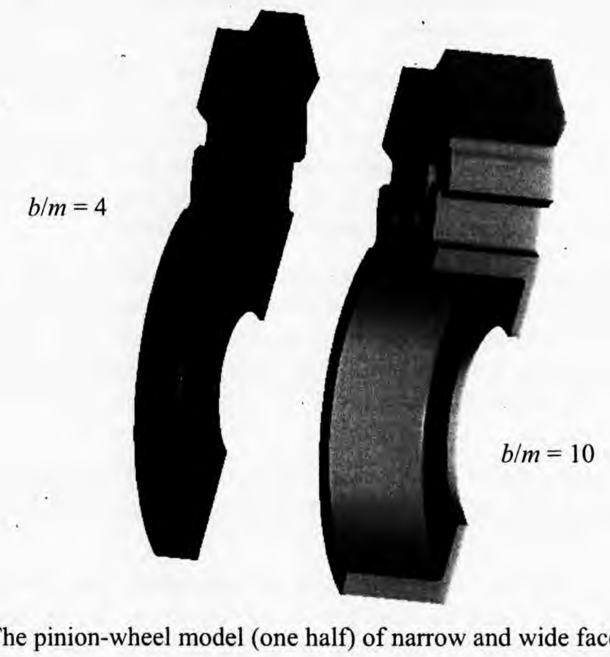

Fig. 1 The pinion-wheel model (one half) of narrow and wide faced thin-rimmed gear

The imposed boundary conditions (loads, constraints, contact) enable the simulation of the torque transmission and load distribution along the tooth face width and are accomplished in accordance with [6].

The deformation δ_R at inner rim surface is calculated and expressed by the magnitude of 3D displacements. The analysis and discussion of the obtained results are performed considering maximum displacements δ_{Rmax} that always axially occur at the tooth edge, regardless of its radial position. Maximum displacements are made dimensionless dividing them by maximum determined wheel displacement δ_{max}.

3. Results and discussion

The dimensionless magnitude of maximum rim displacements $\delta_{Rmax}/\delta_{max}$ related to the rim and web thickness is presented in Fig. 2, a, b, for gear face width b/m =4 and 10, respectively.

Maximum rim displacement approaches maximum gear displacement mostly in the case of narrow faced gear with the considered thinnest web and rim: maximum rim displacement takes almost 50% of maximum gear displacement.

The results of 3D calculations show that the increment of face width results with smaller rim displacements, but this effect vanishes away for the thinnest rim, regardless of the web thickness. The greatest displacement difference related to the face width value, occurs for the rim thickness s_R/h_t =1,33 and web thickness b_s/b=0,1 and 0,2, when the displacements of wide faced gear are 74% of the displacements corresponding to narrow faced gear.

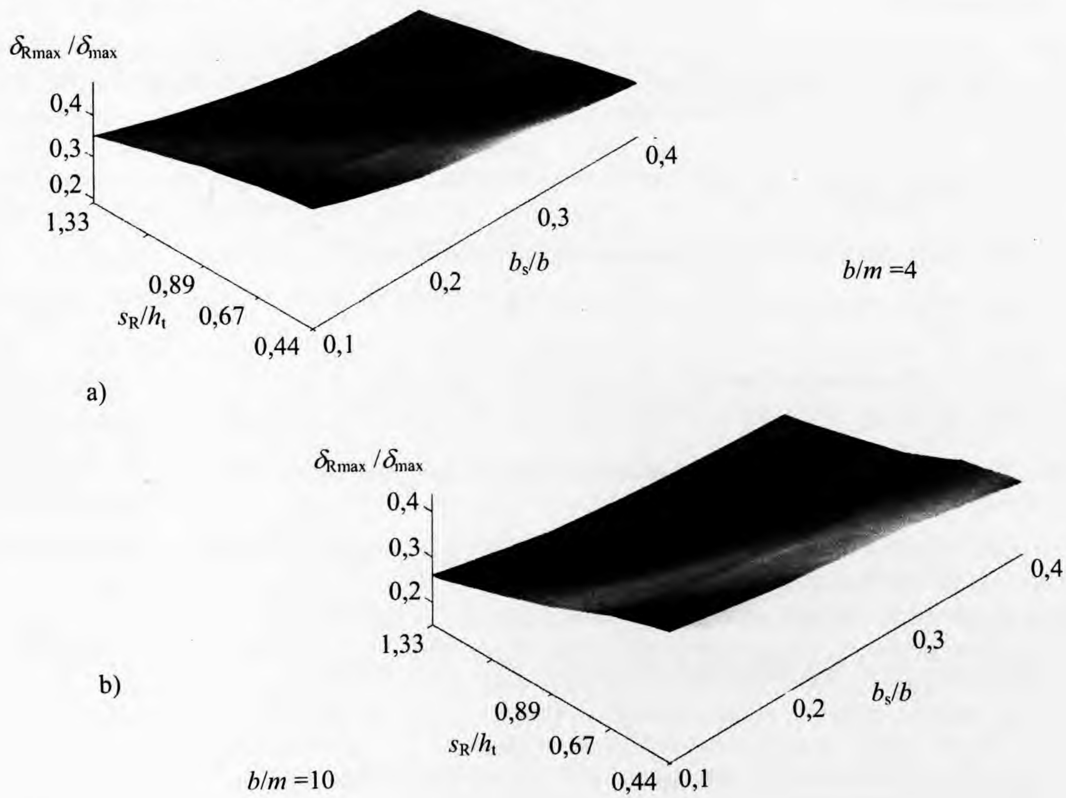

Fig. 2 The dimensionless maximum rim displacements $\delta_{Rmax}/\delta_{max}$ in relation to the rim and web thickness for a) narrow faced gear b/m =4, b) and wide faced gear b/m =10

Maximum displacement δ_{Rmax} / δ_{max} varies more obviously in relation to actual rim thickness for wide faced gear, while in relation to web thickness it varies slightly more for narrow gear.

For thicker webs the decrease of wide faced gear rim thickness effects mostly the displacement increment: the displacements increase more than twice for the thinnest rim (s_R/h_t = 0,44) in relation to about 70% increment for narrow faced gear.

As regards the web thickness, its influence is most obvious for the thickest rim of narrow faced gear, and for the thinnest web the displacement increment is about 84% going from the thickest web, which corresponds to about 73% for wide faced gear.

4. Conclusion

The conclusions that follow describe the modus of thin-rimmed gear rim deformation considering the contribution of rim and web thickness, along with the effects of spur gear three-dimensionality, and can be utilized as directions for design.

Maximum rim displacement approach maximum gear displacement mostly in the case of narrow faced gear with the considered thinnest web and rim, when almost 50% of maximum gear displacement is reached.

The increment of gear body flexibility induced by the decreasing rim thickness, reduces the influence of gear three-dimensionality on the rim displacements, and for the thinnest rim under consideration, going towards thicker webs, there is practically no difference between displacement of wide and narrow faced gear. For thicker rims, the increment of face width results with smaller rim displacements.

Related to the contribution of rim and web thickness to the rim displacements, the attention is to be given more to the effect of web thickness i.e. more to the effect of rim thickness in the case of narrow and wide faced gear, respectively.

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